Running head: A transition from perceptual to category induction

Evidence of a transition from perceptual to category induction in three to nine year old

children.

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Abstract

We examined whether inductive reasoning development is better characterized by accounts assuming an early category bias versus an early perceptual bias. We trained 264 children aged 3 to 9 years to categorize novel insects using a rule that directly pitted category membership against appearance, followed by an induction task with perceptual distractors at different levels of featural similarity; a further 52 children aged 4-7 were tested on a maturity-grouping induction task. Categorization performance was consistently high, however we found a gradual transition from a perceptual bias in our youngest children to a category bias around age 6-7. In addition, children of all ages were equally distracted by higher levels of featural similarity. The transition of strategy is unlikely to be due to an increased ability to inhibit perceptual distractors. Instead, we argue that the transition is driven by a fundamental change in children's understanding of category membership.

Human reasoning depends crucially on our ability to attend to relevant information when making generalizations. This becomes most challenging when the relevant information is not immediately obvious. For example, within the natural world, subtle cues are sometimes better predictors of behavior than overall appearance (e.g., Canadian goslings can only be distinguished from mallard ducklings by subtle differences in their bills and feet, even though the two species have different diets and migration habits, and grow up to look highly dissimilar). Two broad accounts have been proposed to explain the development of category induction and analogical reasoning in young children. The first set of accounts hold that children have an early bias to attend to hidden, non obvious properties and therefore, make generalizations based on kind-information over appearance (category-bias accounts; Gelman, 2003). Similarly, these accounts suggest that young children are capable of reasoning analogically, although are constrained by their knowledge of the relevant relations (Goswami, 1992; 2001). The second set of accounts state that young children intuitively focus on perceptual information when making induction decisions (perceptual-bias accounts; Sloutsky, Kloos & Fisher, 2007), and surface characteristics in analogical reasoning tasks (Gentner, 1988). Children maintain this perceptual / surface bias until they have developed the knowledge base necessary to support a shift towards a focus on category and relational information (a relational shift; Gentner, 1988; Gentner & Rattermann, 1991; Rattermann & Gentner, 1998). Although these two accounts make clear predictions for young children's reasoning strategies, evidence exists to support both category (e.g., Gelman & Markman, 1986) and perceptual (e.g., Sloutsky et al., 2007) biases in young children, which currently makes it impossible to resolve this conflict.

Studies investigating early reasoning biases

Triad paradigms are commonly used to investigate induction strategies since they can directly pit perceptual against category choices (Bulloch & Opfer, 2009; Gelman &

Markman, 1986; Hayes & Thompson, 2007; Opfer & Bulloch, 2007; Sloutsky et al., 2007). A target item is presented alongside two test items, one of which matches the target in category membership but not overall appearance, whereas the other matches the target in overall appearance but not category membership. The child is told a hidden property of the two test items "this puppy hides bones in the ground and this fox hides food in the ground" and asked to generalize this property onto the target item (Gelman & Markman, 1986).

Some studies using triad paradigms have indicated that young children make induction decisions consistent with category context, even when the relationship is not perceptually obvious (e.g. generalizing "bird properties" to a dissimilar looking bird; Gelman & Markman, 1986; see also Gopnik & Sobel, 2000). Category preference has been shown in children as young as 2 years old when items have shared category labels (Gelman & Coley, 1990; also Deák & Bauer, 1996), and children aged 4-5 years have shown a clear preference for category information, even when items were presented with dissimilar labels (for example 'rabbit' and 'bunny'; Gelman & Markman, 1986). Other research has indicated that young children are capable of varying their strategy, depending on context. Opfer and Bulloch (2007) found that when category information was available, children were capable of using this information to make a category-based induction decision. However if no category information was available, then children relied on perceptual similarity (see also Hayes & Thompson, 2007). Together, these studies suggest that children may have an early tendency to focus on category cues beyond overall appearance. Nevertheless, even atypical category members share some perceptual characteristics (Heit & Hayes, 2005). Thus, the apparent category-based decisions observed in the studies described above may have been influenced by perceptual information (Jones & Smith, 1993; McClelland & Rogers, 2003; Rakison, 2000; Rakison & Hahn, 2004; Sloutsky & Fisher, 2004). In order to address this issue, Sloutsky et al (2007) investigated children's default strategies when category and perceptual

cues conflict, allowing perceptual-based versus category-based decisions to be

disambiguated. Children aged 4 to 5 were trained to categorize novel biological stimuli based

on a non-obvious rule (relative number of "fingers" to "buttons"). All other perceptual

features were non-predictive of category membership. Although children were highly

accurate in categorization tasks, they made significantly more perceptual than category

induction choices, thus demonstrating a clear perceptual induction bias. However, the validity

of Sloutsky et al's design has been questioned. Although Sloutsky et al demonstrated that the

children could use the category rule very accurately in the initial and final categorization

tasks, it was unclear whether the children recognized the biological relevance of the category

rule, and therefore may not have been sufficiently motivated to apply this rule in the

induction task. Thus, the apparent perceptual bias Sloutsky et al observed may have been an

artifact of unrealistic stimuli or arbitrary category rules (Gelman & Waxman, 2007).

Evidence for a developmental transition in reasoning strategy

According to perceptual-bias accounts, young children's default strategy is for

perceptual induction, and only once they develop the sufficient knowledge of causal relations

within a domain, can they shift their focus to category and relational cues (Gentner, 1988;

Gentner & Toupin, 1986; Sloutsky et al., 2007). For example, when presented with a straw

and a plant stem and asked how the two items were similar, children aged 5 focused on the

perceptual similarity and said that both items were long and thin, but by age 9 children could

shift their focus to relational similarity and said that both could also carry water: a relational

shift (Gentner, 1988; also see Gentner & Rattermann, 1991; Halford, 1993). As discussed in

Ratterman and Gentner (1998), this shift reflects changes in knowledge representation.

Specifically, young children have better representations of object properties than of the

relations between objects. Only once children have developed sufficient knowledge of the

causal relations within a domain, can they shift their attention away from common object properties towards common relational structure.

However, there are several alternative explanations for apparent inductive transitions in reasoning. Firstly, this may reflect a qualitative change in the nature of children's thinking, rather than a gradual transition with increasing knowledge, perhaps as a result of a stage-like shift in cognitive maturity, akin to a Piagetian shift from preoperational to concrete operational thinking (Inhelder & Piaget, 1958; Piaget, 1964). Secondly, according to Goswami (1992, 2001), young children's natural default is to actively seek relational interpretations, although they may be held back by performance factors, such as knowledge about the relevant relational comparisons. Thus, once children understand the specific relationships that are relevant in a particular context, they will naturally use these relationships over surface characteristics to inform their decisions. Thirdly, a transition could be due to a boost in children's understanding of cue validity: if a child does not recognize the relational connection as a reliable predictor, then they will refer back to perceptual cues (Bulloch & Opfer, 2009). Thus, again, young children may be capable of using relational knowledge, but only use this information when they recognize the relevance of this relational connection to the task. Finally, a child may be capable of using relational knowledge and making induction decisions based on category information, yet does not have the cognitive control to successfully initiate the appropriate response. Even for adults, the likelihood of generalizing properties from one item to another depends on the strength of within-category similarity. For example, Osherson, Smith, Wilkie, López and Shafir (1990) found that the more perceptually similar the items (e.g., robin, bluejay and sparrow versus robin, bluejay and goose), and the more specific the category (e.g., falcon and falcon – shared level: falcon, versus falcon and pelican – shared level: bird), then the greater the strength of the inductive inference (see also Sloman, 1993). In a triad paradigm in which perceptual similarity

conflicts with category membership, the most salient, perceptually similar choice must be inhibited before a category induction decision can be made. In this situation, overcoming highly similar perceptual distractors is likely to be challenging for young children, even if they understand the importance of category membership information (Richland, Morrison & Holyoak, 2006). Thus, there may be no genuine "relational shift". Instead, even young children may be seeking relational information, and become increasingly successful in initiating the appropriate response as they develop in their executive control.

Current study

Each of the broad accounts we have outlined can accommodate evidence that children's responses in reasoning tasks change between ages 2 and 9. In particular, over time, children focus more on category and relational information, and less on salient perceptual characteristics. However, as outlined above, the perceptual-bias and category-bias accounts make different predictions about the mechanisms that drive these developmental changes. We aim to examine developmental changes in children's category induction, using a task which is designed to elicit different predictions from these two broad accounts. Importantly, unlike previous research, this study tested children from multiple year groups (nursery: 3-4 years, through to year four: 8-9 years). This will enable us to examine the developmental trajectory of children's induction strategies, providing a stronger test of category-bias and perceptual-bias accounts.

As in Sloutsky et al (2007), we created novel examples of biological stimuli in order to examine children's early induction biases when the salient perceptual cues are not informative of category membership. Children's understanding of the category rule was confirmed in a stringent test of their categorization performance before and after the induction task. Perceptual and category induction choices were disambiguated by using a triad paradigm in which children were asked to generalize properties from a target item to

either a perceptual or a category choice (as in Bulloch & Opfer, 2009; Gelman & Markman,

1986; Opfer & Bulloch, 2007; Sloutsky et al., 2007). In order to address concerns about the

validity of Sloutsky et al's design (Gelman & Waxman, 2007), we used biologically plausible

stimuli (novel insects) and demonstrated a familiar relational connection through an animated

transition from juvenile to adult. Previous research demonstrates that young children

understand the aging process (see Inagaki & Hatano, 1996 for a review). Therefore, growth

from infancy to adulthood provides a simple way to demonstrate a relational match, whilst

providing a biologically plausible context for changes in perceptual features of the items.

Thus, the category-bias account would predict that as long as children clearly understand this

relationship, then even the youngest children should generalize properties from an adult

insect to the same item depicted as a juvenile, rather than to a different-category adult. In

order to demonstrate that the relational connection is a reliable predictor, the transition from

juvenile to adult will be shown prior to every induction trial.

In Experiment 1a, we examine whether improvements in cognitive control drive a

potential perceptual-category transition, by varying the level of featural similarity between

the target and perceptual distractors. If a pattern of decreasing "distractibility" is observed

along with a parallel transition from perceptual to category induction, then this would provide

an explanation of the transition consistent with category-bias accounts. Specifically, young

children understand the importance of category membership, yet fail to demonstrate their

knowledge due to underdeveloped cognitive control. This outcome would be manifested in an

interaction between distractor-similarity and age: the level of distractor similarity should

affect induction decisions for younger children more than older children. In contrast, if the

transition is independent of featural distraction, then this would support perceptual-bias

accounts, suggesting that children's initial failure to make category-based decisions reflects a

lack of understanding about the importance of category membership rather than an inability

to ignore perceptual distractors. Thus, children only start to use category membership to inform their induction decisions once they've learned to shift their focus away from perceptual features, and towards relational structure (Gentner, 1988; Gentner & Rattermann, 1991; Sloutsky et al., 2007).

Experiment 1a

Method

Participants

Two hundred and sixty four primary school children participated: 57 Nursery (3-4 years; range 3.01-4.04 years; mean = 3.10), 65 Reception (4-5 years; range 4.09-5.09; mean = 5.04), 43 Year 1 (5-6 years; range 5.09-6.09; mean = 6.03), 38 Year 2 (6-7 years; range 6.09-7.09; mean = 7.03), 31 Year 3 (7-8 years; range 7.05-8.03; mean = 7.10), and 30 Year 4 (8-9 years; range 8.05-9.03; mean = 8.11); 133 males and 131 females. An extended age range of six year groups was used in order to better observe a developmental trajectory of the induction shift with age, and whether perceptual distraction decreases. Forty-nine primary school children participated in a similarity pre-test: 10 Reception (4-5 years), 27 Year 1 (5-6 years), and 12 Year 2 (6-7 years); range 4.11-7.10 years; 26 males and 23 females. Twenty three adults (mean age = 26.0 years, range 18-58; 7 males and 16 females) participated in a domain categorization pre-test.

Stimuli

One hundred and ninety two novel insect stimuli were created (42 juveniles, 42 adult targets, 12 High Similarity Distractors (HSDs; these distractors only differed from the relevant adult target by head shape, see Fig. 1a), 12 Low Similarity Distractors (LSDs; these distractors differed from the relevant target on all dimensions apart from the overall size and shade, see Fig. 1b) and 84 transitional images used in the juvenile to adult animations, see Fig. 1c). Most (83%) of the stimuli were only shown once during the experiment, but some

overlap was allowed between initial categorization and induction phases. In order to allow every stimulus to be unique, they all differed on at least one dimension (head shape: round or angled; eyes: orange or white; body: round or triangular; color: purple or green; color of markings: black or white; number of markings: two or four; overall size: small juvenile or large adult; overall shade: pale juvenile or dark adult). In the transition from juvenile to adult, stimuli changed in size, overall shading and grew legs (see Figure 1a).

[Insert Figure 1a here]

During the induction task in the main experiment, children saw 24 triads consisting of an adult target, a same-category but perceptually dissimilar juvenile, and a different-category but perceptually similar adult (see Figures 1b and 1c). To make certain that the target item was perceptually more similar to the perceptual distractor test item than the same-category test item, the similarity between test and target items was validated using child ratings.

[Insert Figures 1b and 1c here]

On 24 triads, children had to choose which test item looked most like the target item. One-sample t-tests confirmed that the perceptual choice was chosen significantly more often than chance. In triads with HSDs, $t(48) = -205.04$; $p < .001$; chosen 98% of the time. In triads with LSDs, $t(48) = -74.70$; $p < .001$; chosen 71% of the time. Thus, children were significantly more likely to pair together items designed to be more perceptually similar to the target (either LSD or HSD, rather than the category choice), therefore validating both as perceptual distractors. To confirm that this effect was stable across the different age groups, a mixed GLM was conducted to investigate the effects of Year (Reception, Year 1 and Year 2: between subjects) and Similarity (HSD and LSD: within subjects) on the percentage of perceptual choices made. As expected, HSDs were chosen more often than LSDs: $F(1,46) = 30.52$; $p < .001$. However, the percentage of perceptual choices was stable across year groups: $F(2,46) = 10.40$; $p = .607$ and there was no interaction between Year and Similarity:

F (2,46) = .384; p = .684. We are therefore confident that children of all ages perceived the distractor as more similar to the target than the category choice, and perceived the HSDs as more similar to the targets than the LSDs.

[Insert Table 1 here]

Finally, a domain categorization pre-test was conducted with adults to check the stimuli were considered to be biologically plausible. They were shown images individually and asked to state whether the item was a living or a non-living thing, and what they believed it to be. It was revealed that adult Sandbugs and Rockbugs were labeled as living kinds 100% of the time, with common responses being 'beetle' and 'bug', juvenile Sandbugs were labeled as living 87% of the time, and juvenile Rockbugs were labeled as living 91.3% of the time, with common responses being 'worm' and 'maggot'.

Procedure

Each participant completed the task individually, in a single session. The procedure was four-fold (as in Sloutsky et al., 2007): 1) category learning, 2) initial categorization, 3) induction task, 4) final categorization.

Firstly, participants were told they would see some bugs growing up. They were presented with a Rockbug and a Sandbug animation (from juvenile to adult; see Figure 1a), without markings, and were told the category rule for each adult and juvenile: "Here is a Sandbug. Sandbugs live in the sand and have round heads for soft burrows. Let's watch it grow up. Now it has grown up, it is still a Sandbug, it lives in the sand and has a round head for soft burrows" or "Here is a Rockbug. Rockbugs live in rocks and have sharp pointy heads for digging. Let's watch it grow up. Now it has grown up, it is still a Rockbug, it lives in rocks and has a sharp pointy head for digging". To ensure participants did not see the critical feature as arbitrary, a function was provided for example, "pointy heads for digging". Participants were told that these bugs came in different colors, shapes and had different

markings, and we could only tell the difference by the head shape. This explanation was provided to help children understand that the other differing dimensions were irrelevant. Participants then completed the category learning phase whereby they were shown eight random trials of Sandbugs and Rockbugs and asked to identify the bug at the juvenile stage, and then again at the adult stage once the transformation was complete. Asking for the name at both stages provided a check that children understood the continuity between juvenile and adult. Feedback was provided, and the participants were reminded of the rule after each juvenile and adult answer, for example, "Yes well done, it is a Rockbug because it lives in rocks and has a sharp pointy head for digging", to re-iterate the functional importance.

In the initial categorization task, children were shown six Sandbug and six Rockbug animations in random order and were asked whether each juvenile and adult was a Sandbug or Rockbug. No feedback was given and the rule was not reiterated.

The induction task consisted of 24 randomized trials (12 Sandbug targets – of which 6 were HSDs and 6 were LSDs – and 12 Rockbug targets – of which 6 were HSDs and 6 were LSDs), each showing a juvenile to adult animation followed by a triad (see Figures 1b and 1c). Each adult target was given a hidden property (relating to its insides e.g., 'cold blood', or its behavior e.g., 'eats flies', based on Gelman and Markman, 1986) and the child was instructed to point to the test item which also had this property. If the child chose the distractor (HSD or LSD), this was coded as a perceptual choice; choosing the juvenile was coded as a category choice. No labels were used to avoid potentially priming the child to select the category choice, simply because it had the same label. Instead, items were referred to as 'this one'.

The final categorization task followed the same procedure as the initial categorization task, but with new stimuli. This task was included to ascertain whether children could

remember the category rules for differentiating between Sandbugs and Rockbugs at the end of the study.

<div align="center">Results and Discussion</div>

Categorization Performance

Only children who performed significantly above chance in both initial and final categorization tasks were included in the final sample. According to a binomial test, scores of 10/12 (83%) and above were significantly above chance (proportion = 0.5, $p = .04$). Forty-three children (2 Year 1, 7 Reception and 34 Nursery children) scored at or below chance and were removed. The remaining 221 children scored highly (see Table 2) and above chance on the initial and final categorization tasks: Initial $M = 99\%$ ($SD = 3.20$), $t (220) = 226.20$; $p < .001$; Final $M = 98\%$ ($SD = 3.80$), $t (220) = 190.67$; $p < .001$.

<div align="center">**[Insert Table 2 here]**</div>

Induction Performance

The percentage of category choices made by each participant in the induction task was examined; with participants who made at least 18/24 category choices considered to have a category-bias (binomial test proportion 0.5, $p = .02$). Participants who made less than 6/24 category choices were considered to have a perceptual-bias (binomial test proportion 0.5, $p = .02$). As shown in Figure 2, the percentage of children with a category-bias increased with age. From Year 2 onwards, the pattern is stable, with a clear majority of children showing a category-bias in each year group.

<div align="center">**[Insert Figure 2 here]**</div>

We used one-sample t-tests to investigate the overall percentage of category choices made by each age group. Nursery children made fewer category choices than expected by chance, indicating a preference for perceptual choices ($t (22) = -4.02$ $p < .001$). Reception children performed at chance, indicating no overall preference for either category or

perceptual choices (t (57) = -1.14; p = .26). Children in Year 1 showed a non-significant trend

towards making more category choices (t (40) = -1.88; p = .07). All groups of older children

made significantly more category choices than expected by chance: Year 2, t (37) = 3.58; $p <$

.001, Year 3, t (30) = 3.03; $p <$ .05, Year 4, t (29) = 3.62; $p <$ .001 (see Table 3).

[Insert Table 3 here]

Twelve hidden properties were each used twice throughout the 24-trial induction task.

A Chronbach's Alpha test confirmed that children's responses were consistent across the

different properties (α = .98). Most children did not justify their responses, but when verbal

comments were made during the induction task, these were noted. Children's responses

generally supported the choice that they made by commenting on either the appearance, or

the category membership of their chosen test item. For example, a comment from a

perceptual-preference Reception child: "That one (*points to distractor*) looks like that one

(*points to target*), so even though they don't have the same head, they're the same"; comment

from a category-preference Year 1 child: "They look like the same kind (*points to target and

distractor*) but that has the same head (*pointing to category choice*) so it must be that one";

comment from a category-preference Year 2 child: "I know [the target and category choice

have the same property] as they have the same head".

Effects of Similarity

The mean percentage of category choices were examined as a function of the level of

similarity of perceptual distractor (HSD versus LSD) across the six year groups. A mixed

GLM (similarity, year) showed a main effect of similarity (HSD versus LSD): F (1, 215) =

26.75; $p <$ .001. As shown in Figure 3, the percentage of category choices for HSD trials was

lower than for LSD trials. As expected, the overall percentage of category choices increased

for older year groups: F (5, 215) = 7.22; p = .001. However, there was no interaction between

similarity and year: F (5, 215) = 148.48; p = .404, indicating a stable effect of featural

similarity for all year groups (Figure 3).

[Insert Figure 3 here]

These findings support the notion that young children's inductive reasoning is

perceptually-based (Sloutsky et al., 2007) and over time there is a gradual transition towards

category-based induction. These findings also show that older children are equally distracted

by higher levels of similarity as younger children, suggesting that the transition towards a

category preference is unlikely to be caused by an increased ability to inhibit highly similar

distractors. However, it could be argued that the apparent transition is not due to the

development of more sophisticated reasoning, and is instead due to changes in the types of

category information children consider to be important. Specifically, it is possible that

younger children were making choices based on maturation categories (adult vs. juvenile).

This could explain why younger children tended to generalize properties from the target adult

to the distractor choice (which matched the target in maturity), whereas older children tended

to generalize properties to the juvenile, which matched the target in terms of taxonomy (bug

category). This issue was addressed in Experiment 1b.

Experiment 1b

The aim of Experiment 1b was to examine whether children who showed an apparent

perceptual-bias were in fact basing their choice on maturation (pairing the adult target with

another adult). In Experiment 1a, an animation from juvenile to adult was used to emphasize

the relationship between the two items: the juvenile and adult were from the same category

(in fact, they were exactly the same item – the adult was the "grown up" version of the

juvenile). We confirmed that children understood this relationship by asking them to label the

juvenile and adult items in the initial and final categorization tasks. We were therefore

confident that if children understood the importance of category information, then they would use this information in the induction task. However, this design created a further grouping that could be used to inform category-decisions, specifically, the maturity of the target and test items. Experiment 1b followed the same format as Experiment 1a, except that two conditions were compared where the category-choice varied in maturity (juvenile or adult). The 'juvenile as category choice' trials (hereafter referred to as juvenile trials) were the same as the HSD condition from Experiment 1a: 12 induction triads with an adult target, an adult HSD and a juvenile category choice. In the 'adult as category choice' trials (hereafter referred to as adult trials) there were 12 induction triads with an adult target, an adult HSD and an adult category choice which differed from the target on shape, color, markings and marking color, but had the same head shape. If younger children used maturation to inform their induction decisions, they would make more maturity-based choices in the juvenile trials (when the target and the distractor were adults and the category-choice was a juvenile) than in the adult trials (when all three items were adults). This is because participants could use maturity information in the former condition, but not in the latter condition. If younger children used perceptual information to inform their induction decisions, then they would choose the distractor item in both conditions, since this item was always the most similar to the target. Since Experiment 1a demonstrated that most children transition from a perceptual to a category bias sometime between Reception and Year 2, we focused on these three age groups.

<div align="center">Method</div>

Participants

Fifty-two primary school children participated: 17 Reception (4-5 years; range 4.04-5.03 years; mean = 4.09), 16 Year 1 (5-6 years; range 5.04-6.03 years; mean = 5.09) and 19 Year 2 (6-7 years; range 6.00-7.03 years; mean = 6.08); 21 males and 31 females.

Stimuli and Procedure

The design and procedure replicated Experiment 1a but with two counterbalanced blocks of trials in the induction task. One of the blocks showed the 12 HSD triads from Experiment 1a, the other showed 12 new triads including an adult target, an adult HSD and an adult category choice. The four-fold methodology and hidden properties replicated Experiment 1a and children's data were removed if they were unable to pass either the initial or final categorization tasks.

Results and Discussion

Four children (3 Reception and 1 Year 2) scored at or below chance in either the initial or final categorization tasks and were removed from the following analyses. The remaining 48 children scored highly and above chance on the initial and final categorization tasks: Initial $M = 99\%$ ($SD = 2.67$), t (47) = 126.97; $p < .001$; Final $M = 98\%$ ($SD = 3.65$), t (47) = 92.03; $p < .001$.

As in Experiment 1a, a gradual transition was found from perceptual preference to category preference. Figure 4 shows the percentage of children in each year group who made significantly more category choices, perceptual choices, or showed no bias. We used one-sample t-tests to investigate the overall percentage of category choices made by each age group. Reception children made fewer category choices than expected by chance, indicating an overall preference for perceptual choice: t (13) = -2.13; $p = .05$. As shown in Figure 4, only 14% of Reception children showed a category bias, and as a group, they were biased towards perceptual choices. This differs from our finding in Experiment 1a that the Reception children showed no significant bias as a group. This is perhaps because Experiment 1b was conducted earlier in the school year, so the children were slightly younger than those in the Experiment 1a sample. Year 1 children performed at chance, indicating no overall preference for either category or perceptual choices: t (15) = .21; $p = .836$. The majority of Year 2

children (64%, as shown in Figure 4), showed a significant bias to make the category choice but this bias was not significant for the group as a whole: t (17) = 1.55; p = .141. Again, this is likely to be because the children were slightly younger in this sample.

[Insert Figure 4 here]

Effects of Maturity

A mixed GLM (maturity, year) was conducted and showed no effect of maturity (juvenile trials vs. adult trials): F (1, 45) = .071; p = .791. As shown in Figure 5, the percentage of category choices for juvenile trials and adult trials was comparable, indicating that children were not making their choices through maturation groupings and were instead either relying on category or perceptual cues. There was a non-significant trend towards an effect of year (Reception, Year 1, Year 2) with the number of category choices increasing for older year groups: F (2, 45) = 2.70; p = .078. There was no interaction between maturity and year: F (2, 45) = 1.18; p = .316, indicating that all age groups were equally unaffected by the maturity of the category choice.

[Insert Figure 5 here]

As in Experiment 1a, we found a gradual transition from the majority of children showing a bias towards perceptual information through to the majority of children showing a bias towards category information. The same pattern was shown, regardless of the maturity of the category choice. These findings suggest that there are no clear developmental changes in the types of category information children consider to be important. Therefore, it is unlikely that the younger children in Experiment 1a were making choices based on maturation categories. Instead, it is much more likely that the transition reflected a genuine change in focus from perceptual to category induction.

General Discussion

We investigated two broad accounts of the development of children's inductive strategies. Specifically, we examined whether young children's default preference is for perceptual or category induction, and by testing multiple year groups we could investigate whether a developmental trajectory was observed. As in Sloutsky et al (2007), we used novel examples in order to disambiguate category-based and perceptual-based induction choices. However, we also addressed the concerns of Gelman and Waxman (2007) by using examples of plausible biological kinds and demonstrating the relational connection between same-category items using a highly familiar relationship (growth from juvenile to adult). Importantly, we also addressed whether a perceptual to category transition is driven by a decrease in featural 'distractability'. Specifically, whether the transition is due to children becoming better at inhibiting high similarity distractors through improved cognitive control (Richland et al., 2006).

Our work provides support for perceptual-bias and relational shift accounts (Gentner & Toupin, 1986; Sloutsky et al., 2007), as we observed a gradual developmental transition in inductive reasoning strategy away from a perceptual bias, towards a category bias in 3 to 9 year old children. As expected, we found that participants were more distracted by higher perceptual distractors (Osherson et al., 1990; Sloman, 1993). However, an interesting and novel observation is that children at all ages were equally influenced by the level of similarity of the distractor. Thus, this transition cannot be explained by an increased ability to inhibit or ignore salient, but irrelevant, perceptual cues. Instead, the perceptual to category transition occurs independently of children's ability to ignore highly similar perceptual distractors.

Young children's default induction strategy

These findings make an essentialist bias towards non-obvious category information in early induction unlikely. Gelman (2003) argues that children have an early bias to attend to hidden, non obvious properties and thus, make generalizations based on kind-information

over appearance. Similarly, Goswami (1992; 2001) argues that young children's natural default is for relational interpretations. Once children understand the specific relations relevant to the task, then their decision will be based on these. Bulloch and Opfer (2009) also argue that young children are capable of using relational information when they recognize this as a reliable predictor. In Experiment 1a, the target had a very strong relationship to the category-choice. It was not only the same type of bug; it was the very same bug, grown up. The connection between the juvenile (category choice) and adult target was demonstrated prior to every trial when the child witnessed the juvenile bug being transformed into the adult target bug. In addition, children's understanding of the two different types of bugs (Sandbugs and Rockbugs), and the continuity between juvenile and adult bugs was confirmed in the categorization phase both before and after the induction phase. Instead, our findings provide support for research suggesting that the natural default for induction in young children is perceptual (Inhelder & Piaget, 1958; Piaget 1964; Sloutsky et al., 2007). It is striking to note that the very young children who passed the strict categorization criteria, showed a significant bias not to apply this category rule during the induction task, and instead reverted to induction based on perceptual cues. Nevertheless, there are three main alternative explanations for our findings in Experiment 1a. Firstly, the perceptual choice was arguably more distinctive than the category choice (larger, with more salient features), thus young children may have been drawn to this item. Secondly, young children may have been using category information, just not the information we intended them to use. Specifically, it is possible that they chose the perceptual choice because this matched the target in maturity and was therefore more likely to share properties with the target than the juvenile. Finally, children may have been basing their responses on basic-level category information, and thus considered either type of bug to plausibly share properties with the target (Waxman, Lynch, Casey & Baer, 1997). The first two concerns are neatly addressed in Experiment 1b, which

confirmed that the same percentage of category choices were made in the "adult trials" as well as in the "juvenile trials". Thus, children's decisions were stable, even when the category choice and distractor were equally salient, and even when the category choice was the same age as the target. Finally, it is unlikely that children's performance can be explained by a focus on basic-level information since children were trained to focus on the differences between the categories, and were proficient in defining items by their specific name by the time they reached the induction phase. In addition, if children believed that either choice were a plausible basis for induction, then they should have responded at random, choosing either the juvenile or adult distractor, because both were bugs and therefore either could share the properties at the basic level. However, the majority of children showed a bias either for the perceptual or the category choice. Only a minority showed no clear bias at each age group. In contrast, there is a clear transition from the majority of children showing a bias for perceptual choices through to a majority bias for the category choice. Thus, by far the most plausible interpretation of our findings is that young children showed a bias towards the perceptual distractor because they did not appreciate the importance of category information in making induction decisions.

The influence of perceptual similarity on induction

Previous studies have used varying levels of perceptual similarity between target and test items which could be a key factor behind their contradictory findings. For example, Sloutsky et al (2007) used an explicit manipulation of appearance similarity, such that the perceptual (distractor) choice had the same overall appearance as the target. In contrast, Gelman and Markman (1986) selected real biological kind examples (e.g., squirrel one, squirrel two, rabbit). Although these were selected so that the overall appearance similarity between target and distractor was greater than between target and category-choice, the salience of the perceptual distractor will have been much less than in Sloutsky et al's study,

allowing more children to successfully make the category choice. Thus, a comparison of these studies reveals a pattern consistent with Osherson et al (1990) and Sloman's (1993) work with adults. Specifically, fewer inductive category choices were made when perceptual similarity was higher (as in Sloutsky et al., 2007), and more inductive category choices were made when perceptual similarity was lower (as in Gelman & Markman, 1986). This crude comparison demonstrates how the choice of stimuli can affect the apparent inductive preference choice, and ideally, we need to compare stimuli at different levels of similarity within the same study. In Experiment 1a, we specifically investigated whether different levels of perceptual similarity between the target and distractor item could encourage different inductive preferences. Our findings demonstrated a clear, consistent influence of perceptual similarity on induction decisions. Crucially, there was no interaction between age and level of similarity; having a highly similar distractor present during the induction task caused children of all ages to make fewer category choices. Thus, an increased ability to ignore highly similar distractors is unlikely to drive the transition from a perceptual to a category bias. We do not mean to rule out the influence of inhibition in supporting children's induction decisions. Clearly, the children who made category choices must have successfully inhibited the more salient perceptual choice. However, we cannot interpret the failure of the younger children to make category choices simply in terms of poor inhibition, because all ages of children were equally affected by the level of similarity of the perceptual distractors. Thus, although inhibition may play a role in supporting children's induction choices, the ability to ignore perceptual distractors is significantly not enough to drive the transition from perceptual to category induction. Below, we discuss more likely interpretations of this transition.

Developmental changes in induction strategy

Although we are not the first to suggest a qualitative shift in children's thinking during their first few school years (Gentner, 1988; Piaget, 1964; Sloutsky et al., 2007), we

have presented the first systematic evidence of a perceptual to category transition in induction strategy. The key question remaining concerns the driving force behind this transition; we go some way towards deciding between potential mechanisms. Firstly, we have demonstrated that the development of category induction is unlikely to be driven by an early bias to attend to non-obvious categorical information, since there is no evidence of an early focus on category information in induction. In contrast, there is clear evidence of an early bias to use perceptual information, even though young children are highly proficient in categorizing the items. Secondly, the development of category induction, although possibly supported by inhibition, is not triggered by an increased ability to inhibit high similarity distractors, since all age groups were equally influenced by the level of similarity between distractor and target. Thirdly, children are not making their inductive decisions based on maturity groupings or attention grabbing features such as size, and are instead focusing on either the appearance or the category of the items presented. Instead, the most likely explanation of this transition is that young children's reasoning is biased toward perceptual features, and only later do they start to incorporate category information into their induction decisions. Thus, the younger children in our sample didn't make category choices because they didn't appreciate the importance of category membership when making inductive decisions.

These findings are potentially consistent with either a stage-like cognitive maturation account (Piaget, 1964) or a gradual shift in the development of analogical reasoning (Gentner, 1988) and category induction (Sloutsky et al., 2007) due to an accumulation of knowledge. We argue that the gradual nature of the transition makes the second account more likely. It is inevitable that the older children in our sample had greater knowledge of biological kinds and were therefore more attuned to the relationship between category membership and behavior. Thus, this heightened understanding of the importance of category relationships in the biological domain caused the older children to become increasingly more

attentive to relational structure, biasing them to use category information to make induction decisions (Gentner, 1988; Gentner & Rattermann, 1991; Halford, 1993; Rattermann & Gentner, 1998). In conclusion, our findings demonstrate that a qualitative change occurs in children's reasoning between the ages of 3 and 9, independent of inhibition capabilities, in which they begin to appreciate of the importance of category information in explaining the properties and behavior of biological kinds. This appreciation enables children to look beyond the obvious when making induction decisions about natural kinds, and is likely to scaffold increasingly sophisticated reasoning more generally.

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Tables

Table 1

Mean scores for the percentage of perceptual choices during LSD and HSD trials, for each year group

Year Group	Mean % LSD choices (SD)	Mean % HSD choices (SD)
Reception	69% (4.79)	91% (2.81)
Year 1	74% (3.81)	99% (.27)
Year 2	67% (3.49)	99% (.29)

Table 2

Mean scores for the initial and final categorization tasks for each year group

Year Group	Mean initial score (SD)	Mean final score (SD)
Nursery	96% (4.00)	97% (3.10)
Reception	98% (4.00)	97% (4.53)
Year 1	99% (2.65)	98% (4.55)
Year 2	99% (3.02)	98% (4.02)
Year 3	99% (1.44)	99% (1.00)
Year 4	100% (0.00)	99% (0.73)

Table 3

The percentage of category induction choices for each year group.

Year Group	Mean initial score (SD)
Nursery	26% (28.10)
Reception	43% (43.60)
Year 1	61% (38.14)
Year 2	72% (37.57)
Year 3	71% (38.07)
Year 4	75% (37.64)

Figure Captions

Figure 1a. The juvenile to adult transformation: in the category learning and the initial and final categorization tasks, participants completed randomized trials showing juvenile to adult transformations and were asked whether each juvenile and adult was a Sandbug or a Rockbug.

Figure 1b. An example of an induction trial with a High Similarity Distractor: the juvenile is transformed into an adult target (transformation), then the adult target is shown with a category choice (bottom figure) and a perceptual choice (top figure; induction triad).

Figure 1c. An example of a category induction trial with a Low Similarity Distractor: the juvenile is transformed into an adult target (transformation), then the adult target is shown with a category choice (bottom figure) and a perceptual choice (top figure; induction triad).

Figure 2. The percentage of children showing each type of bias across the six year groups.

Figure 3. The mean percentage of category choices made when distractor was either a HSD or a LSD for each age group.

Figure 4. The percentage of children showing each type of bias across the three year groups.

Figure 5. The mean percentage of category choices made when the category choice was either a juvenile or an adult.